NR 323-21

भारतीय प्रौद्योगिकी संस्थान खड़गपुर
खड़गपुर-७२१ ३०२
Indian Institute of Technology Kharagpur
Kharagpur – 721302

Mid-Semester Exam

Date: ______ **FN/AN** **Time: 2 hours; Full Marks: 60** **Number of Students: 260**
Spring Semester - 2017-2018 **Department: E & ECE** **II year B. Tech.**
Subject no. EC 21008 **Subject name: Analog Electronic Circuits**

Instructions:

1. Answer either all questions in Part-A or all questions in Part-B. Do not answer some from Part-A and some from Part-B.
2. Answers to all sub-parts of a question must be at one place.
3. Wherever it is necessary, you may use assumption(s) with reasonable justification.
4. Assume BJTs are in active mode and MOSFETs are in saturation for the circuits where numerical values of bias voltage and currents are not given.
5. For BJTs unless otherwise stated use, $|V_{BE(on)}| \approx 0.6V$, $|V_{CE(sat)}| = 0.3V$, $V_A = 100$ V, and $V_T = 26$mV. For NMOS and PMOS, unless otherwise stated, assume $\mu_n C_{ox} = 200\ \mu A/V^2$, $\mu_p C_{ox} = 100\ \mu A/V^2$, and $V_{TH} = 0.4$ V for NMOS devices and -0.4 V for PMOS devices. Assume $\lambda = 0$ wherever not given.

**********************Part-A**********************

1. Assume $\lambda = 0$, compute W/L of M_1 in Fig. 1 such that the device operates at the edge of saturation. **[2 marks]**

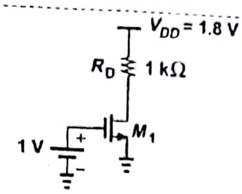


Fig. 1

2. Consider the circuit shown in Fig. 2 **[2 marks]**
(a) If $I_{S1} = 2I_{S2} = 5 \times 10^{-16}\,A$, determine V_B such that I_X = 1.2 mA.
(b) What value of Rc places the transistors at the edge of the active mode?
Note: Edge of active mode is the condition when voltage at base is equal to the voltage at the collector.

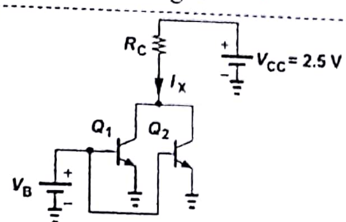


Fig. 2

3. Determine the region of operation of Q_1 in Fig. 3. Assume $I_{S2} = 5 \times 10^{-16}\,A, \beta = 100$, and $V_A = \infty$. **[3 marks]**

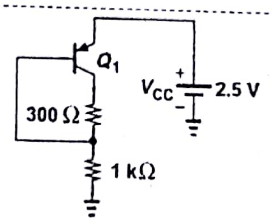
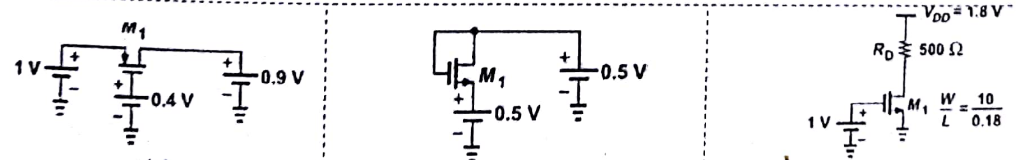


Fig. 3

4. Determine the region of operation of M_1 in the circuits in Fig. 4: **[1+1+1=3 marks]**



(a) (b) (c)

Fig. 4

5. A common emitter (CE) amplifier circuit is shown in Fig. 5. Given values of the circuit components are: $R_1 = 188$ kΩ, $R_2 = 52$ kΩ, $C_1 = C_2 = 1\ \mu F$, $C_L = 50$ pF, $V_{CC} = 12$V, Forward current gain of the transistor, $\beta = 200$ and $I_S = 1 \times 10^{-16}\,A$. **[7 + 5 + 6 + 5 + 2 = 25 Marks]**

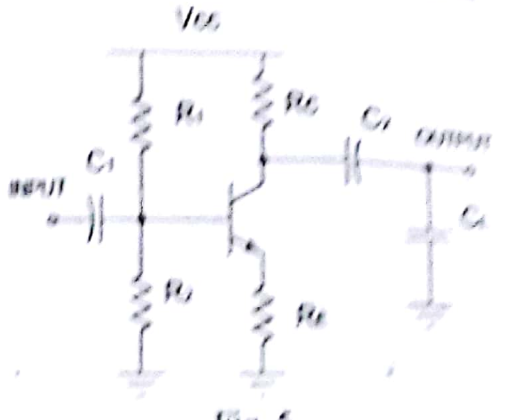


Fig. 5

(i) **Find the values** of R_E, R_C, and I_C such that voltage drop across R_E is ≈ 0.25 V and DC voltage at collector is 6 V. Use these value of R_E and R_C for the subsequent parts of this question. **Hint:** You have to solve it iteratively and you cannot assume $I_B << I_{R1}$.

(ii) **Draw small signal equivalent circuit** of the amplifier. Using the small signal equivalent circuit, **derive the expression** of effective transconductance of the amplifier.

(iii) **Find the values** of **output impedance, voltage gain,** and **input impedance**, using the above small-signal model.

(iv) For an input signal of $v_{in} = 1 + 0.05 \times sin(2000\pi t - 180^o)$ volts, **neatly sketch** (including d.c. level and the phase) the voltage waveforms at the base, emitter and collector nodes of the transistor.

(v) How can we **increase the gain** of the amplifier? What is the **value of the gain** of the amplifier with your suggested modification?

6. Consider the circuit of Fig. 6, where a common-source stage (M_1 and R_{D1}) is followed by a common-gate stage (M_2 and R_{D2}).
(a) Writing $V_{out}/V_{in} = (V_X/V_{in})(V_{out}/V_X)$ and assuming $\lambda = 0$, compute the overall voltage gain. *Avoid drawing small-signal model to arrive at the conclusion. Decouple the circuit cleverly to arrive at the solution using the concept of effective G_m and R_{out}.*
(b) Simplify the result obtained in (a) if $R_{D1} \rightarrow \infty$. Explain why this result is to be expected. **[4+4+2 = 10 Marks]**

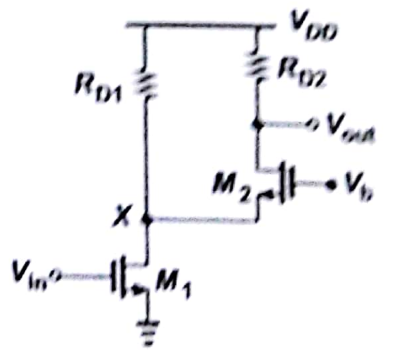


Fig. 6

7. Obtain the transfer function $\frac{V_{out}}{V_{in}}(s)$ for the circuit in Fig. 7.
(a) by first annotating all the capacitors in the circuit.
(b) then doing an exact analysis *i.e.*, drawing the small signal model.
(c) Obtain the transfer function by associating a pole with each node.
(d) Do the results in (b) and (c) above match? If yes, why and if no, why not. **[2+7+5+1 = 15 Marks]**

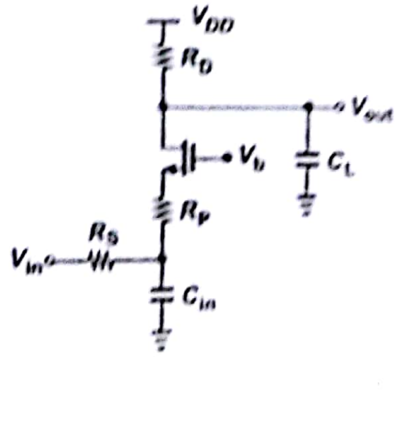


Fig. 7

**********************Part-B**********************

1. Determine the operating mode of the transistor in Fig.1. [3 marks]

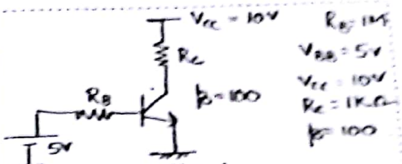


Fig. 1

2. Find out the emitter, base and collector current for the circuit shown in Fig.2. [3 marks]

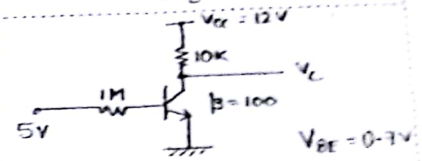


Fig. 2

3. Find range of values of R_c for the transistor in Fig.3 to be in active mode. [3 marks]

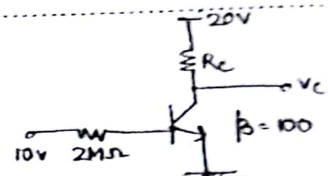


Fig. 3

4. Find range of values of R_D and R_S for the circuit in Fig.4. [3 marks]

$I_D = 0.4mA$
$V_D = 0.5V$
$V_t = 0.7V$
$\mu_n C_{ox} = 100\mu A/V^2$
$W/L = 32$

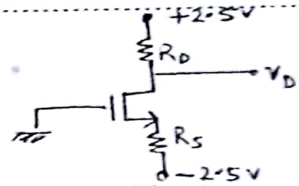


Fig. 4

5. Calculate the values of R and V_d for the transistor in Fig.5. [3 marks]

$I_D = 80\mu A$
$V_t = 0.6V$
$\mu_n C_{ox} = 200\mu A/V^2$
$L = 0.8\mu m$
$W = 4\mu m$

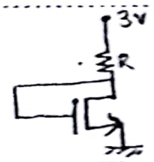


Fig. 5

6. A transistor amplifier using bias circuit is shown in Fig.6.
   a) Find out the dc emitter current and a.c resistance of the circuit.
   b) Draw the small signal equivalent circuit and find out the following:
      i) Voltage gain
      ii) Current gain
      iii) Input resistance
      iv) Output resistance.

[3+4+4+4+4 =15 Marks]

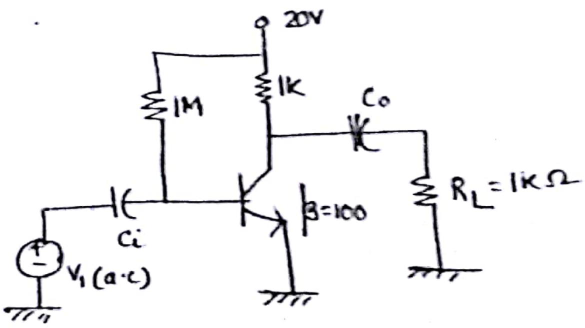


Fig. 6

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7. Consider the bipolar amplifier in Fig.7.
a) Calculate the values of g_m, r_π and r_o
b) Determine the small signal a.c model for the transistor and draw the resistance equivalent circuit.

[5+10 = 15 Marks]

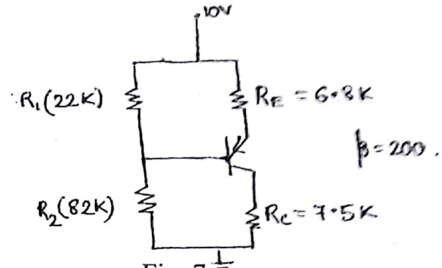

Fig. 7

8. A MOSFET device is used in the common source amplifier circuit.
a) Determine the quiescent quantities I_D and V_{DS}.
b) What is the mutual conductance g_m of the MOSFET.
c) Draw the small signal equivalent circuit of the amplifier.
d) Determine the small signal voltage gain.

[3+3+5+4 = 15 Marks]

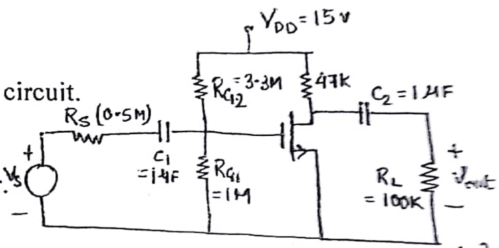

Fig. 8

****************End of Part-B*****************